

# LEACH CORPORATION CONTROLS DIVISION

## LEM Recorder (Astronaut's Memo Pad) Miniature Tape Recorder/Reproducer

Designed by Leach for Grumman Aircraft Engineering Corp.

- 10 hours recording time in 51 cubic inches
- Survival probability: 0.9998 for 10-hour mission
- Less than 3% p/p flutter @ 9g rms vibration



### DESIGN REQUIREMENTS

Design a voice-actuated memo pad recorder for use by astronauts aboard the Apollo Lunar Excursion Module.

It must provide a total capacity of 10 hours recording time yet occupy an overall volume of less than 51 cubic inches. The weight is limited to 2.3 pounds and power consumption to 2.4 watts. Minimum acceptable probability of survival: 0.9965.\*

It must perform with less than 3% p/p flutter while subjected to 15g acceleration; 52g, 11 ms,  $\frac{1}{2}$  sine shock (survival only); and 9g rms random vibration. It must also operate over pressure variations from sea level to hard vacuum, temperature from 0 to +160°F and combined salt fog, high humidity and exposure to 100% oxygen.

\*Through the use of high reliability components and techniques, Leach increased the predicted survival probability to .9998 for the 10 hour... a 15 to 1 increase over the original requirement.

#### SPECIFICATION SUMMARY

PURPOSE	Astronauts Memo Pad aboard Apollo Lunar Excursion Module Vehicle.
FUNCTION	Record only device with playback for go, no-go monitoring.
TAPE CAPACITY	450 feet x ¼" wide.
SIZE	6.22" x 2.05" x 4.0", 51 cubic inches
WEIGHT	2.3 pounds.
POWER	2.4 watts, 115 volts, single phase, 400 cps
HEAD GEOMETRY	4 track interlaced. Record and Reproduce.
DATA CAPACITY	1 channel for 10 hours using four tracks and head switching with bidirectional transport operation.
FREQUENCY RESPONSE OR BIT RATE	300 - 5.2 kc with 300 - 3.0 kc audio, 4.4 kc $\pm 5\%$ Time code modulated FM carrier and 5.2 kc reference mixed.
SIGNAL TO NOISE RATIO	35 db
DYNAMIC ENVIRONMENTS	15g Acceleration 52g, 11 MS, ½ Sine Shock (survival only) 9g rms random vibration with 3% p/p flutter.
CLIMATIC ENVIRONMENTS	0-160°F, hard vacuum, sand and dust, salt spray.
RELIABILITY REQUIREMENTS	0.9998 for a 10 hour mission Life - 5000 hours

#### DATA CAPACITY, SIZE AND WEIGHT

The astronauts memo pad is an outstanding example of efficient utilization of available space, weight and power. Tape waste is minimized by VOX operation and a fast (50 ms) start time. The direct recording technique is used since it provides the highest packing density/inch of tape.

Through the judicious selection of modulation and multiplexing techniques, the unit records voice data from 300 cycles to 3 kc, a time code modulation FM carrier in the 4.1 kc to 4.7 kc range, and a 5.2 kc reference, all on a single track operating at a tape speed of 0.6 ips. While separate tracks for each would have permitted a slower tape speed, this would have reduced the signal to noise ratio on playback. The additional amplifiers required



would have added weight and power. Increasing the speed for reproduce would vary the time base and make the voice unintelligible.

The fast start time, already available for the voice operation, enables the recorder to provide rapid reversal and head switching with less than a 100 millisecond interruption at the end of each full tape pass. The operating speed of 0.6 ips provides 2.5 hours of record time per pass with the 450 feet of 1/2 mil tape in each cartridge. By providing logic for head switching and tape drive reversal, the record time was extended to 10 hours using four separate tracks in serial operation.

Cordwood construction and recently developed heat removal techniques permit the packaging of all record electronics in less than 13 cubic inches. This includes a direct record amplifier, time code input filter, voltage controlled oscillator, VCO output filter, reference oscillator, bias oscillator, power supplies, self test circuits and complex control logic.

The tape cartridge employs negator spring tensioning principles so that the tape is always under tension even with power removed or with the cartridge removed from the recorder. The cartridge provides physical protection of recorded tape and a convenient means of transferring the recorded information to the Leach-built ground reproduce equipment where audible voice and visual display of the time in days, hours, minutes and seconds is accomplished.

#### ENVIRONMENTAL RESISTANCE

The LEM voice and time recorder represents a significant advance in the state of the art for light weight, low speed tape operation in vibration environments. By employing dual capstans, a dynamically and statically balanced reeling assembly, a 2 phase hysteresis synchronous capstan drive motor and a rigidly controlled tape path, flutter is kept below 3% peak to peak. This specification is cumulative from DC to 1 kc while the equipment is being subjected to a 9g random vibration.

#### PERFORMANCE

It might be assumed that the combination of direct audio, multiplexed FM and multiplexed reference, all sharing the available direct record/reproduce dynamic range would reduce the quality or the integrity of the data. Yet design proof tests indicate that signal to noise on the audio channel is maintained at better than 35 db broad band over the 300 cps to 3 kc range. The integrity of the digital bits extracted from the FM carrier is adequate to ensure that no greater than 1 bit is missed in  $10^6$ . The 5.2 kc reference is used for the reproduce transport capstan servo control.

The controlled reproduce transport will correct speed errors of  $\pm 25\%$  and flutter of 10% p/p so that time base stability for both the audio and the time correlation data is preserved. Tests were conducted by intentionally introducing errors up to these limits and results showed correction to within 1%.

## FLEXIBILITY

The original device was intended to record multiplexed information on a single track when powered by single phase, 115 volts, 400 cps spacecraft power. It can also be modified to accommodate up to seven tracks, provide analog, digital, or FM record and reproduce and to operate from unregulated DC power. All this is accomplished without changing the transport design. The equipment has already demonstrated its ability to record up to 1000 bits/inch/track on four tracks with fewer than 3 in  $10^7$  missed bits.

Conversion to an all digital multiple track record/reproduce device increases the weight to five pounds and the size to approximately 120 cubic inches. Power is increased to approximately 5 watts. This 2:1 increase in size, weight and power is primarily due to the additional signal conditioning (read/write) amplifiers and power conversion equipment. The data capacity of a device modified in this manner is over 46 million bits including parity and/or error correction bits.

# LEACH

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